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AERATION OF WHEY WASTES

II. A COD AND SOLIDS BALANCE

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This report summarizes recent laboratory investigations on whey aeration and supplements a previous publication (1) showing that whey wastes may be readily treated under certain conditions without nitrogen addition. Under the conditions of that experiment, sludge accumulation occurred when 1,000 mg/l of whey were oxidized in the presence of 2,000 mg/l of sludge. The series of experiments was continued, and a balance of influent and effluent material was assembled. These supplementary studies present information on COD oxidation, sludge build-up, sludge losses from the aerators, and purification potentialities.

Experimental Procedure

Two aerators were kept in operation for a period of 96 days. One aerator received natural whey; the other received the same whey supplemented with ammonia to give a COD:N ratio approaching that of dairy wastes. Temperature was maintained at approximately 30°C by submerging the glass jar aerators in a water bath. Aeration was by means of a turbine-type agitator which dispersed air supplied at the rate of 1.5 volumes per minute and provided excess aeration for the process.

In the course of the previously reported work, it was observed that a definite sludge increase was occurring, longer settling times were necessary, and that some sludge was being lost in the effluent. From that time, 35 days after the initiation of the experiment, the effluents were carefully recovered, measured, and analyzed. The COD of the starting sludge was 4,419 mg/l in the natural whey treatment tank and 4,038 mg/l in the N-supplemented tank. Over the following period of 61 days, a total of 576 g of whey was added to each aerator in 48 doses. Whey feedings were omitted over week-ends although aeration was continued.

The regimen employed was as follows:

To the 4 l of sludge which had been aerating overnight were added 12 g whey solids and 8 l water (plus 0.80 ml concentrated NH_4OH containing 175 mg N to the supplemented tank). The mixed sludge liquor was aerated and agitated for 1.5 to 2 hr prior to settling of the sludge for 1.5 to 3 hr, as necessary. All material above the 4-l mark was removed by siphon. Aeration and agitation were resumed until the next feeding period. The 8 l removed as effluent were thoroughly mixed and sampled for analysis. Since in most cases analyses could not be performed immediately, 4 drops of concentrated H_2SO_4 were added to each 40-ml sample to arrest microbial activity. These samples were refrigerated for future COD assay.

Effluents were of varying clarities; some were almost clear while others were quite turbid. Great variations were also observed in amounts of cellular material present. A 25-ml portion of the fresh effluent was immediately filtered through asbestos on a Gooch

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TABLE I.—COD Balance in a 61-Day Study in Which Dilute Whey Was Added 48 Times to Aerating Sludge

Item	Natural Whey (g)	Whey +Nitrogen (g)
Whey (2.34% H_2O)	576.0	576.0
Whey carbon	219.4	219.4
Whey COD (calculated)	585.1	585.1
Whey COD (assay)	592.1	592.1
Whey nitrogen (2%)	11.3	11.3
Nitrogen added	0	8.4
Total nitrogen	11.3	19.7
COD:N	52:1	30:1
Sludge, start COD	53.0	48.5
Sludge, final COD	74.4	75.4
Sludge increase, COD	21.4	26.9
Effluent COD	112.9	138.3
COD remaining	134.3	165.2
COD remaining	22.7*	27.9*
COD oxidized	458.8	426.9
COD oxidized	77.3*	72.1*
Filtrate COD	18.8	12.7
Possible COD removal	573.3	579.4
Possible removal	96.8*	97.9*
COD oxidized per day	7.5	7.0
COD available per day	9.7	9.7

* Per cent.

crucible. The residual material was dried at 105°C for 24 hr, cooled, weighed, and reported as effluent sludge solids. The filtrate was acidified and refrigerated for later COD determination.

Results

Table I summarizes the data and presents a COD balance on 61 days of operation. The whey used in these studies contained 2.34 per cent moisture, and the analysis on the moisture-free basis showed it to have 75.1 per cent lactose, 2.0 per cent nitrogen (12.5 per cent protein), 4.37 per cent ash, and a carbon content of 39.0 per cent. The 576 g of whey added in 48 feedings were calculated to have 585.1 g COD from its carbon content. Actual analysis by a rapid assay (2) gave 592.1 g COD which was the value used in these studies. This same amount of whey contained 11.3 g nitrogen, giving a COD : N ratio of 52 : 1. Nitrogen supplementation of 8.4 g in the second tank gave a total of 19.7 g of nitrogen or a COD : N ratio of 30 : 1 which was comparable to skim milk or dairy wastes.

Sludge accumulated in both tanks, amounting to an increase of 21.4 g COD with treatment of natural whey and 26.9 g COD in the other tank. A considerable amount of COD was present in the 8-l effluents collected by siphoning—112.9 and 138.3 g. Thus, of the 592.1 g whey COD entering the systems, 22.7 and 27.9 per cent was not oxidized, while about 75 per cent was oxidized. It should be noted that only 2 to 3 per cent soluble COD remained in the filtrate. Therefore, a potential purification of 97 per cent is possible under proper conditions of separation.

Over the 61-day period of this experiment, the average amount of natural whey COD disappearing by oxidation was 7.5 g/day from an available 9.7 g, or 77 per cent. The accumulated data on solids balance (Table II) corroborates these findings. The 25 feedings made in the last 35 days of the experiment amounted to 300 g whey solids, 78 per cent of which was oxidized. Nitrogen supplementation had a negative influence.

The available data can be used to determine the amounts of whey and sludge oxidized. First, assuming that 62.5 per cent of the available COD of whey wastes is converted to cell COD, the 9.7 g (Table I) should produce 6.1 g of cell COD by the assimilation process (3). The theoretical amount

TABLE II.—Solids Balance of Last 25 Feedings in 35 Days

Item	Natural Whey (g)	Whey +Nitrogen (g)
Whey added	300.0	300.0
Effluent sludge	65.1	83.7
Solids oxidized	234.9	212.7
Solids oxidized	78.3*	70.9*
Solids oxidized per day	6.7	6.1
Solids available per day	8.6	8.6

* Per cent.

oxidized to carbon dioxide, therefore, will be 3.6 g. Since there was a total COD of 7.5 g oxidized per day, the remaining 3.9 g were apparently lost through sludge burn-up and thus establish daily sludge oxidation rate of 5.24 per cent. An accumulation of sludge occurred equivalent to 6.1 g produced less the 3.9 g oxidized or 2.2 g COD.

The rate of whey feeding and of sludge oxidation necessary to maintain a state of dynamic equilibrium may be calculated easily. If only 7.5 g whey COD were added, 4.7 g would have been converted to cells and 2.8 g would have been eliminated as carbon dioxide. If 74.4 g sludge COD are assumed as the initial concentration, the sludge oxidation rate would have been 6.32 per cent. Daily oxidation of 10 units of whey COD should be possible by 100 units of sludge cells. The 12 g whey feedings would have required 120 g sludge COD or 96 g sludge. This sludge oxidation rate slightly exceeds the 5.5 per cent recently reported by Kountz and Forney in their study on activated sludge total oxidation metabolism (4). The value is somewhat less than that proposed by the 6-hr Warburg study on skim milk wastes by Hoover and associates (5) in which it was estimated that 10 to 20 per cent of the sludge is oxidized per day. The latter value was used by Kountz in designing a rapid ejector aeration process for the treatment of dairy wastes (6)(7).

Wuhrmann (8), in discussing the factors affecting efficiency and solids production in the activated sludge process, stated that it is theoretically possible to run a plant without any sludge production provided no insoluble and unfermentable solids are introduced with the waste. Under actual operating conditions, however, an ideal environment for total sludge oxidation rarely has been attained; and slight quantities of substances that cannot be oxidized within the aeration tank are formed. Yet, total oxidation plants are in use. The success of dairy waste aeration plants led Tapleshay (9) to the application of this type of treatment to municipal and other wastes. Purifications of 75 to 90 per cent in the presence of sludge concentrations of 3,000 to 12,000 mg/l were obtained with long periods of aeration. However, an occasional wasting of sludge is necessary. Likewise, the complete mixing activated sludge system devised by McKinney *et al.* (10) was designed to operate without production of excess sludge, yet solids are expected to increase slowly. Ettinger (11) emphasized the use of lengthy aeration times to avoid disposition of excess sludge and to avoid nitrogen supplementation. That nitrogen supplementation was not necessary is demonstrated in this current study. The effluent was withdrawn shortly after the whey had been assimilated and before extensive sludge oxidation had taken place. Additional aeration oxidized the sludge and released nitrogen to meet the demands of synthesis for subsequent assimilation and oxidation of the whey wastes.

Summary

1. COD and solids balances are presented for an extended period of whey waste aeration in which the sludge-whey mixture contained 1,000 mg/l whey.

2. An average of 75 per cent of the influent whey COD was oxidized. With proper removal of sludge from the effluent, a purification of 97 per cent is possible.

3. Although a sludge COD oxidation rate of 5.2 per cent per day was obtained, sludge accumulation occurred.

4. Nitrogen supplementation of whey waste offered no advantages in the regimen employed.

5. Calculations show a possibility of a dynamic equilibrium when 100 units of sludge are used to treat 10 units of whey, based on a 6.3 per cent per day sludge oxidation rate.

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